Chapter 4
Attendant Problems and Responsibilities

4-1. Boat Discharges

Due to the limited circulation in most small boat basins, the discharge of pollutants from boats can have adverse environmental impacts. Primary boat discharges include sanitary wastes and boat motor emissions.

a. Sanitary waste.

(1) Sanitary waste discharges from boats pose a health risk and can potentially violate state water quality standards, especially for boat basins located near bathing or shellfishing waters. Boat sewage can be visually repulsive (Chmura and Ross 1978) and may contribute to increased BOD in receiving waters (NOAA 1976). BOD is a measure of the DO required to stabilize the decomposable matter present in a water body by aerobic biochemical action. When BOD increases, DO available for aquatic organisms decreases. Anaerobic waters create a sump for pollutants and organics resulting in stagnant, sulfide-odorous, and slow-decaying (due to low DO) conditions.

(2) The most serious effect of discharging fresh fecal material is the potential for introducing disease-causing viruses and bacteria (pathogens). Problems may occur if boat sewage is released in the vicinity of shellfish (clam or oyster) beds or into enclosed waterways with limited flushing. Shellfish require clean water to be microbiologically safe for human consumption, regardless of whether they are eaten raw or partially cooked (USEPA 1985).

(3) Management of boat sanitary waste discharges includes the installation and proper use of equipment onboard the vessels and onshore equipment for collection and disposal. The onboard equipment is referred to as marine sanitation devices (MSD). Another means of managing boat sanitary waste discharges would be to educate boaters about the potential health risks associated with the discharge of sewage. Boat toilet use would be reduced if marinas discouraged "live-aboards" and provided well-maintained shoreside restroom facilities of sufficient quantity to accommodate above-average boating populations. Shoreside facilities must be convenient to the docks (Chmura and Ross 1978). USEPA does not require a National Pollutant Discharge Elimination System permit for: "Any discharge of sewage from vessels, effluent from properly functioning marine engines, laundry, shower, and galley sink wastes, or any other discharge incidental to the normal operation of a vessel." However, this exclusion doesnot apply to permanently moored vessels.[1] Permanently moored vessels could be discouraged from marinas in order to avoid potential discharge of any sewage from all vessels into aquatic habitats by applying to the USEPA Administrator for issuance of a regulation prohibiting discharge into well-defined shellfish growing waters (USEPA 1985).

b. Boat motor emissions.

(1) Boat motor emissions include hydrocarbons and lead. Once exhausts are released from outboard motors, some of the hydrocarbons become suspended in the water column while others evaporate at the surface (Kuzminski, Jackivicz, and Bancroft 1973). Clark, Finely, and Gibson (1974) suggested that small amounts of hydrocarbons from outboard motor wastes may adversely affect mussels and oysters. They found that mussels were more sensitive to two-cycle outboard motor effluent than oysters, and that cumulative mortality in mussels after 10 days was 66 percent compared with 14 percent for oysters.

(2) The major source (approximately 88 percent) of lead that enters a basin through subsurface outboard motor exhaust was the combustion of leaded gasoline, which is no longer available (May and McKinney 1981). Lead is very toxic to most plants and is moderately toxic to mammals, where it acts as a cumulative poison (Bowen 1966). The aquatic organisms most sensitive to this metal are fish (Mathis and Kevern 1975). Boat motor emissions can be reduced through the increased use of unleaded fuels and by manufacturer research and development aimed at reducing the pollutants in emissions and increasing fuel efficiency. Public education directed toward the importance of well-tuned engines in reducing emissions and increasing efficiency is another mitigative measure to be considered (USEPA 1985).

4-2. Water Quality Monitoring and Maintenance

a. Sewage discharge from vessels moored in a boat basin is normally a minimal pollution problem. However, the development of recreation facilities will result in replacement of existing lands with impervious surfaces, increases in contaminants and surface runoff, and increased siltation.

[1] Letter from Roger O. Olmstead, Program Manager, Shellfish Sanitation, USFDA, Atlanta, GA to J. David Clem, Chief, Shellfish Sanitation Branch, 1 December 1982.

If small boat basin design results in a confined basin, there is the potential for stagnation and eventual accumulation of pollutants. This can result in decreases in dissolved oxygen levels below acceptable levels. The basin should be oriented so that flushing currents are introduced. Design components to encourage flushing include taking advantage of prevailing winds; elimination of corners or projections in basin design; and shaping and sloping of the bottom of the basin. In severe cases, flushing can be achieved by pumping water from an adjacent area or by aerating the basin.

b. Water quality monitoring can be expensive. The most economical alternative compared to field monitoring may be the use of a numerical model. All models require some field data for proper calibration. Tetra Tech (1988) determined that a better and more cost-effective approach would be a combination of both water quality monitoring and numerical modeling. These models may be used to predict flushing time and pollutant concentrations without site-specific data. Another advantage of numerical models over field monitoring is the ability to perform sensitivity analyses to establish a set of design criteria. Numerical models may be used to evaluate different alternative designs to determine the configuration that would provide for maximum flushing of pollutants. These models may also be used to perform sensitivity analysis on the selected optimum design.

4-3. Environmental Effects of Structures

Breakwaters and jetties associated with marinas, boat ramps, or harbors can benefit aquatic biota. Gravel and cobble provide substrate for small plants, crustaceans, and molluscs, which are food for fishes and waterfowl (Miller 1988, Payne 1989). In addition, rock structures create quiescent areas that are used by larval and juvenile fishes, as well as freshwater mussels and crustaceans. Jetties and other rock structures may be particularly beneficial if they are placed in lakes or estuaries where substrate consists mainly of fine-grained sands and silts. The negative effects of these structures probably originate from improper construction practices. Heavy equipment should be kept clear of shallow aquatic habitats, wetland vegetation, and unstable banks. Coarse rock and riprap are the best materials for construction of jetties and other rock structures. Although automobile bodies and rubble from construction can be used in place of riprap, this material is unsightly and can be dangerous forswimmers and may be a source of toxicants or nuisance flotsam.

a. Marinas.

(1) The impacts of small boat basins are dependent on the sensitivity of the site selected, the design of the marina, and the extent of the impacts on the environment. The nature of a small boat basin dictates the need for protected waters that are conducive to stagnation and associated water quality problems. Basins that contain dead-end canals and are inadequately flushed may create major water quality problems. Stagnation may result in higher temperatures and salinities in the basin than in unmodified areas. Poor circulation may also result in the buildup of debris, organic material in the water and sediments, phytoplankton blooms, depletion of oxygen in the water, and associated fish kills (de La Cruz 1983; McBee and Breham 1979). There are a number of design features that can be considered to improve the environmental quality of a harbor. The shape of the basin is important. It should fit the flow patterns of the area if possible. This requires avoiding square-shaped basins and dead-end canals that create dead-water areas. Basins should be constructed so that they are not deeper than their access channel. The most desirable design would be a marina with a wide deep entrance channel with gradually decreasing depths toward the inner harbor (NOAA 1976). This design would provide improved flushing rates in the marina. With this design, larger vessels could be moored toward the mouth of the marina and shallower draft vessels in inner portions of the harbor. Flow-through designs would also be desirable. Open piles and floating breakwaters would be more conducive to water circulation in a basin. Where an open flow-through design is not feasible, breaches or culverts should be considered to enhance circulation and flushing of the basin. A small boat basin should not be located near sewage or industrial outfalls that may compound potential water quality problems.

(2) Water quality in the harbor may be further impacted by boating activities. Petroleum products may be released in the water from boat engines. Boating operations may also add to the turbidity of the water in the basin if it is shallow and may result in a reduction of photosynthesis and dissolved oxygen in the water. Generally, a water depth of 2-3 ft between the propeller of a vessel and the bottom during low water should prevent these problems (NOAA 1976). Other water quality problems may result from oil spills, sewage disposal, and land runoff into the basin. Contamination may also result from protective paints (copper) on boats.

(3) Noise and air pollution from construction and/or operation of a marina may also disturb aquatic and terrestrial animals and humans in the immediate area.

b. Jetties.

(1) Jetties associated with marinas are structures used to stabilize the position of the navigation channel, to shield vessels from wave forces, and to control the movement of sand along the adjacent beaches so as to minimize the movement of sand into the channel (EM 1110-2-1204). The sand transported into a channel will interfere with navigation depth. Because of the longshore transport reversals common at many sites, jetties are often required on both sides of a channel to achieve complete channel protection. It is the impoundment of sand at the updrift jetty that creates the major physical impact. When fully developed, the impounded sand extends well updrift on the beach and outward toward the tip of the jetty.

(2) Another major physical impact of a jetty is the erosion of the downdrift beach. Before the installation of a jetty, nature supplies sand by intermittently transporting it along shore. The reduction or cessation of this sand transport due to the presence of a jetty leaves the downdrift beach with an inadequate natural supply of sand to replace that carried away by littoral currents.

(3) To minimize the downdrift erosion, some projects provide for periodically dredging the sand impounded by the updrift jetty and pumping it through a pipeline to the downdrift eroding beach. This pumping provides nourishment of the downdrift beach and also reduces shoaling of the channel. If the sand impounded at the updrift jetty extends to the head or seaward end of the jetty, sand will move around the jetty and into the channel, causing a navigation hazard. Therefore, the purpose of sand bypassing is not only to reduce downdrift erosion, but also to help maintain a safe navigation channel.

(4) One design alternative for sand bypassing involves a low section or weir in the updrift jetty over which sand moves into a sheltered, predredged deposition basin. By dredging the basin periodically, channel shoaling is reduced or eliminated. The dredged material is periodically pumped across the navigation channel to provide nourishment for the downdrift shore.

c. Breakwaters.

(1) Breakwaters are wave energy barriers designed to protect any land form or water area behind them from the direct assault of waves (EM 1110-2-1204). Because of the higher cost of these offshore structures, breakwaters have been mainly used for harbor protection and navigational purposes. In recent years, shore-parallel, detached, or segmented breakwaters have been used for shore protection structures.

(2) Breakwaters have both beneficial and detrimental effects on the shore. All breakwaters reduce or eliminate wave action in the lee (shadow). However, whether they are offshore, detached, or shore-connected structures, the reduction or elimination of wave action also reduces the longshore transport in the shadow of the breakwater. For offshore breakwaters, reducing the wave action leads to a sand accretion.

(3) Shore-connected breakwaters provide protection to harbors from wave action and have the advantage of a shore arm to facilitate construction and maintenance of the structure (Figure 4-1).

(4) At a harbor breakwater, the longshore movement of sand generally can be restored by pumping sand from the side where sand accumulates through a pipeline to the eroded downdrift beach.

(5) Offshore breakwaters have also been used in conjunction with navigation structures to control channel shoaling. If the offshore breakwater is placed immediately updrift from a navigation opening, the structure impounds sand in its lee, prevents it from entering the navigation channel, and affords shelter for a floating dredge plant to pump out the impounded material across the channel to the downdrift beach.

d. Physical considerations.

(1) Jetty, breakwater, and marina construction are invariably accompanied by localized changes in the hydrodynamic regime, creating new hydraulic and wave energy conditions. The initial disruption of the established dynamic equilibrium will be followed by a trend toward a new set of equilibrium conditions. Rapid dynamic alterations in the physical environment may occur in the short-term time scale as the shore processes respond to the influence of the new structures. Slower, more gradual, and perhaps more subtle changes may occur over the long term.

(2) In light of the dynamic character of shore processes, assessment of the effects of coastal engineering projects on shorelines is a difficult task. Shoreline changes

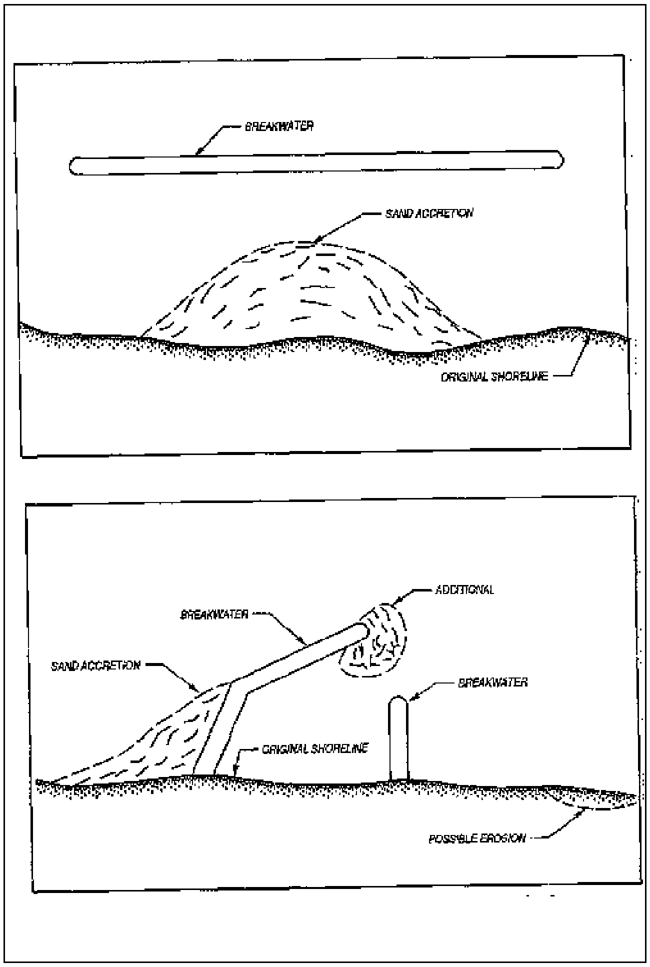

Figure 4-1. Erosion and accretion patterns in association with detached and attached breakwaters

induced by the presence of a structure may be masked by wide annual or seasonal fluctuations in natural physical processes. Several events, however, can be predicted in response to jetty, breakwater, and marina construction with reasonable certainty. For example, by creating wave-sheltered areas, construction will result in changes in the erosional and depositional patterns along adjacent beaches, both inshore and offshore. A jetty or shore-connected breakwater will form a barrier to longshore transport if the structure extends seaward beyond the surf zone. Spatial extent of the ensuing shoreline alteration will depend on the structure's effectiveness as a sediment trap, which is a function of its orientation to the prevailing wave climate. Updrift accretion of sediments will continue until the sink area is filled to capacity and the readjusted shoreline deflects longshore transport past the seaward terminus of the jetty. The volume of sediment trapped by the structure represents material removed from the natural sand bypassing process. Consequently, the downdrift shoreline will be deprived of this sediment and become subject to erosion. In circumstances where waves are refracted around the structures in a proper manner, accretion can occur along the seaward side of a downdrift jetty. Reflection of waves from a jetty or breakwater may also cause erosion of adjacent shorelines. However, erosion further down the shoreline is not precluded. Planning for adequate sand bypassing is, in view of the above considerations, a critical requirement of coastal construction.

(3) Erosion related to jetties will not necessarily be limited to downdrift shorelines. Jetties confine flows through a channel such that current velocities are increased. An enhancement of ebb jet flows will result in displacement of sediments from between the jetties in a seaward direction to deeper waters.

(4) Shore-connected breakwaters of a small boat basin affect shorelines in much the same manner as jetties. Accretion occurs along the updrift junction of shore and structure and continues until longshore transport is deflected around the free end to the breakwater (Figure 4-1). Calm waters in the protected lee of the breakwater provide a depositional area that can rapidly shoal. Sediments trapped in the accretional area and terminal shoal are prevented from reaching downdrift beaches, and substantial erosion may result.

(5) Offshore breakwaters create depositional areas in their "shadows" by reflecting or dissipating wave energy (Figure 4-1). Reduction of wave energy impacting a shoreline in the lee of the structure retards the longshore transport of sediments out of the area and accretion ensues. The extent of accretion will depend on the existing balance of shore processes at a given project site. Generally, a cuspate spit will develop between the shoreline and the structure as the system approaches a new equilibrium. However, if the breakwater is situated in the littoral zone such that it forms a very effective sediment trap, a complete connection will eventually form, merging the shoreline with the structure. A tombola associated with an offshore breakwater may present a severe obstruction to littoral transport and trap a significant volume of sediment. Extensive downdrift erosion may result.

(6) By modifying the cross-sectional area of a channel, jetty construction potentially can alter the tidal prism, or volume of water entering or exiting through a channel in one tidal cycle. Enlarging a channel can increase the tidal range within a harbor. In connection with channel deepening, seawater may intrude further into the harbor than occurred under pre-project conditions. Circulation

patterns within a basin may be altered as a consequence of modified floodwater current conditions. Thus, the area physically affected by jetty construction might be extended appreciable distances from the actual project site.

e. Water quality considerations.

(1) Suspended sediments. During the construction and dredging of a small boat basin, suspended sediment concentrations may be elevated in the water immediately adjacent to the operations (EM 1110-2-1204, U.S. Army Corps of Engineers 1989, NOAA 1976). In many instances, however, construction and dredging will be occurring in naturally turbid estuarine or coastal waters. Plants and animals residing in these environments are generally adapted to, and are very tolerant of, high suspended sediment concentrations. The current state of knowledge concerning suspended sediment effects indicates that anticipated levels (generally less than l,000 mg/l) generated by construction and dredging do not pose a significant risk to most biological resources (U.S. Army Corps of Engineers 1989). The adaptability of the animals to high turbidities may minimize environmental impacts. However, turbidity control is always in the best interest of the environment during construction or dredging activities. Although estuaries and coastal waters are generally more turbid than coral reefs, they are not insensitive to potentially indiscriminate construction practices. High levels of suspended sediment concentrations remain a concern in construction projects. Limited spatial extent and temporal duration of turbidity fields associated with these construction activities reinforce this assessment. However, when construction and dredging are to occur in a clear-water environment, such as in the vicinity of coral reefs or sea grass beds, precautions should be taken to minimize the amounts of resuspended sediments. Organisms in these environments are generally less tolerant to increased siltation rates, reduced levels of available light, and other effects of elevated suspended sediment concentrations (U.S. Army Corps of Engineers 1983, EM 1110-2-1204). Potential negative impacts can be somewhat alleviated by erection of a floating silt curtain around the point of impact when current and wave conditions allow. However, high-energy conditions usually preclude the use of silt curtains (NOAA 1976, EM 1110-2-1202).

(2) Other water quality impacts. Indirect impacts on water quality may result from changes in the hydrodynamic regime. The most notable impact of this type is associated with breakwaters which form a semi-enclosed basin used for small boat harbors or marinas. If the flushing rate of the basin is too slow to provide adequate removal of the contaminants, toxic concentrations may result (USEPA 1985, NOAA 1976, U.S. Fish and Wildlife Service 1980, EM 1110-2-1204). Also, fluctuations in parameters such as salinity, temperature, dissolved oxygen, and dissolved organics may be induced by construction or due to altered circulation patterns. Anticipated changes in these parameters should be evaluated with reference to the known ecological requirements of important biological resources in the project area.

f. Biological considerations.

(1) Habitat losses. Measurable amounts of bottom habitat are physically eradicated in the path of a fixed jetty or breakwater during construction of a small boat basin. If a rubble-mound structure with a toe-to-toe width of 164 ft (50 m) is used as an example, 0.6 mile (1 km) of structure removes approximately 12.5 acres (5 ha) of preexisting bottom habitat (EM 1110-2-1204). Once a structure is in place, water currents and turbulence along its base can produce a scouring action, which continually shifts the bed material. Scour holes may develop, particularly at the ends of structures. Scouring action may effectively prevent the colonization and utilization of that habitat area by sediment-dwelling organisms. Effects of scouring are largely confined to entrance channels and narrow strips of bottom habitat immediately adjacent to structures. Usually, only a portion of the perimeter of a structure will be subject to scouring, such as along the channel side of the downdrift jetty. Generally, the amount of soft bottom habitat lost at a given project site will be insignificant in comparison with the total amount of that habitat available. Exceptions to this statement may exist, such as where breakwater construction and dredging of the total enclosed harbor area will displace large acreages of intertidal habitat. Often such habitats function as nursery areas for estuarine-dependent juvenile stages of fishes and shellfish, and the availability of those habitats will be a determining factor in the population dynamics of these species. Most marina projects, however, require only a small amount of dredging. The impacts of these projects will be minor provided marshes, sea grasses, and other critical habitat are not disturbed. Dredged material should be placed on high ground within the marina area, if possible (NOAA 1976). Dredged material can be used to improve coastal ecosystems if it can be disposed in a manner to establish artificial marshes, sea grass beds, and shellfish beds (NOAA 1976, EM 1110-2-5026, Pullen and Thayer 1989). Additional habitat losses may occur when significant erosion of downdrift shorelines impacts spawning or nesting habitats of fishes, shorebirds, or other organisms and when the tidal range of a harbor is

modified by entrance channel modification, which in turn affects coastal habitat. Short-term impacts of this type may also occur during construction activities as heavy equipment gains access to the project site. Small boat basins in some coastal regions are constructed in areas of rocks or other hard bottoms and may require blasting to break up the rocks during construction. Fish kills may result from the blasting. The major damage is to fish with swim bladders. Tests have shown that a force of 40-50 psi from a high explosive charge is usually fatal to adult fish with swim bladders, whereas a charge as low as 2.7 psi will kill juveniles (U.S. Army Corps of Engineers 1989).

(2) Habitat gains.

(a) Losses of benthic (bottom) habitat and associated benthos (bottom-dwelling organisms) due to physical eradication or scouring will gradually be offset by the gain of new habitat represented by the structures themselves and the biological community, which becomes established thereon (NOAA 1976, EM 1110-2-1204). The trade-off made in replacing "soft" (mud or sand) bottom habitat with "hard" (rock, at least in rubble-mound structures) bottom habitat has generally been viewed as a beneficial impact associated with jetty and breakwater projects. Submerged portions of jetties and breakwaters, including intertidal segments of coastal structures, function as artificial reef habitats and are rapidly colonized by opportunistic aquatic organisms. Over the course of time, structures in marine, estuarine, and most freshwater environments develop diverse, productive, reeflike communities. Detailed descriptions of the biota colonizing rubble-mound structures have been made for project sites on the Pacific (Johnson and De Wit 1978), Atlantic (Van Dolah, Knott, and Calder 1984), Gulf of Mexico (Hastings 1979; Whitten, Rosene, and Hedgpeth 1950), and Great Lakes (Manny et al. 1985) coastlines. In some geographical areas, jetties and breakwaters provide the only nearshore source of hard-bottom habitat. Also, exposed portions of detached structures may be colonized by seabirds.

(b) The ultimate character of the biological community found on a jetty or breakwater of a small boat basin will depend on the quality of habitat afforded by the construction materials used. Physical complexity (i.e., rough surfaces with many interstitial spaces and a high surface area to volume ratio) is a desirable feature of rubblemound structures in comparison with the relatively smooth, flat surface of steel sheet-pile, concrete bulkhead, caisson structures (EM 1110-2-1204, NOAA 1976, U.S. Fish and Wildlife Service 1980). The sloping sides of rubble-mound structures also maximize the surface area of habitat created. Structures with sloping sides also provide more habitat within a given depth interval than structures with vertical elements. Where depths are sufficient, the biota on jetties and breakwaters exhibit vertical zonation, with different assemblages of organisms having discrete depth distributions. In general, then, structures built in deep waters will support a more diverse flora and fauna than those in shallow waters. This pattern will be influenced by such factors as latitude and tidal range.

(c) Just as changes in shoreline configuration and beach profile can entail habitat loss, they can also represent habitat gain. Accretional areas, such as exposed bars, and the above-water portion of structures may be used, for example, by wading and shorebirds for nesting, feeding, and resting sites.

(3) Migration of fishes and shellfishes.

(a) Eggs and larvae. Early life history stages, namely eggs and larvae, of many important commercial and sport fishes and shellfishes are almost entirely dependent on water currents for transportation between spawning grounds and nursery areas (EM 1110-2-1204). A concern which has sometimes been voiced by resource agencies in relation to jetty projects is that altered patterns of water flow may adversely affect the transport of eggs and larvae. Those eggs and larvae carried by longshore currents might be especially susceptible to entrapment or delay in eddies and slack areas formed adjacent to updrift jetties at various times in the tidal cycle. Even short delays in the passage of eggs and larvae may be significant because of critical relationships between the developmental stage when feeding begins and the availability of their food items. All aspects of this potential impact remain hypothetical. No conclusive evidence exists to support either the presence or absence of impacts on egg and larval transport. This fact is true even where jetties have been present for relatively long spans of time. The complexity of the physical and biological processes involved would render field assessments of this impact a long-term and expensive undertaking. The results of hydraulic modeling studies related to this question have been inconclusive (U.S. Army Corps of Engineers 1980). Future modeling studies combined with field verification studies may provide insight into resolving the validity of this concern.

(b) Juveniles and adults. Similar concern has been voiced regarding potential impacts of jetties and breakwaters on migration of juvenile and adult fishes and shellfishes. These stages generally have well-developed swimming capabilities, such that physical barriers imposed by these structures are less of a concern than are behavioral barriers. This issue has been raised primarily in association with projects in the Pacific Northwest, and with anadromous fishes in particular (Faurot et al. 1989). Anadromous fishes, including many salmonids, spend much of their adult life in the ocean, then return to fresh water to spawn. Early life history stages spend various lengths of time in fresh water before moving downstream to estuaries where the transition to the juvenile stage is completed. Specific concerns are that juveniles or adults will not circumvent structures that extend for considerable distances offshore. Juveniles in particular are known to migrate in narrow corridors of shallow water along coastlines and may be reluctant, due to depth preferences, to move into deeper waters. The State of Washington has developed criteria whereby continuous structures that extend beyond mean low water are prohibited. Designs of coastal structures there are required to incorporate breaches or gaps to accommodate fish passage (EM 1110-2-1204).

(4) Increase predation pressure. Coastal rubble-mound structures provide substrate for the establishment of artificial reef communities. As such, jetties and breakwaters serve as a focal point for congregations of fishes and shellfishes which feed on sources of food or find shelter there. Many large predator species are among those attracted to the structures in numbers, as evidenced by the popularity of jetties and breakwaters as sites of intense sport fishing. Thus, there is concern, again largely associated with projects in the Pacific Northwest, that high densities of predators in the vicinity of jetties and breakwaters pose a threat to egg, larval, and juvenile stages of important species (Faurot et al. 1989). For example, fry and smelt stages of several species of salmon are known to congregate in small boat harbors prior to moving to the sea. The concern raised is that these young fishes are exposed to numerous predators during their residence near the structures. As is the case with the concern for impacts on migrating patterns, this concern remains a hypothetical one. Conclusive evidence demonstrating the presence or absence of a significant impact is unavailable and will be exceedingly difficult to obtain.

g. Environmental summary.

(1) Environmental design.

(a) Every small boat basin project scenario should incorporate engineering design, economic cost-benefit, and environmental impact evaluations from the inception of planning stages. All three elements are interrelated to such a degree that efficient project planning demands their integration. Environmental considerations must not be an afterthought. Structural design criteria should seek to minimize negative environmental impacts and optimize yield of suitable habitat for biological resources. Minimizing impacts can best be achieved by critical comparisons of a range of project alternatives, including the alternative of no construction. From an environmental perspective, site selection is perhaps the single most important decision in the planning process. However, various engineering design features can be incorporated to optimize an alternative from an ecological viewpoint. For example, opting for a floating rather than fixed breakwater design might alleviate most concerns related to impacts on circulation, littoral transport, and the migration of fishes, because passage is allowed beneath the structure. Floating breakwaters are also excellent fish attractions and still provide substrate for attachment and shelter for many other organisms.

(b) In planning small boat harbors, configurations that minimize flushing problems should be examined. Rectangular basins that maximize the area available for docks and piers characteristically have poor water circulation, particularly in the angular corner areas. Designs with rounded corners and entrance channels located so that flood tidal jets provide adequate mixing throughout the basin are desirable. Selection of a less steep rubble-mound side-slope angle will maximize the availability of intertidal and subtidal habitat surface areas. The size class of stone used in armor layers of rubble-mound structures is another engineering design feature that has habitat value consequences. Selection of large-size material results in a heterogeneous array of interstitial spaces on the finished structure. Heterogeneity rather than uniformity enhances the quality of the structure in terms of refuge and shelter sites for diverse assemblages of fishes and shellfishes.

(2) Environmental assessment.

(a) Short-term impacts. Actual construction activities for small boat basins entail a number of potential impacts (Table 4-1). These impacts will vary in type and frequency from project to project. For example, temporary or permanent access roads may have to be built to allow transportation of heavy equipment and construction materials to the site. The access routes may cross marshes, creeks, and other water areas and have the potential for altering water circulation and displacing valuable wildlife habitat. Grading, excavating, backfilling, and dredging operations will generate short-term episodes of noise and air pollution and may locally disturb wildlife such as

Table 4-1
Marina Environmental Impact Matrix (NOAA 1976)

FACILITY COMPONENTS* / IMPACT CATEGORIES**	Alteration of Natural Areas***	Alteration of Water Circulation Patterns***	Turbidity	Release of Sewage	Oil Spills	Land Runoff	Erosion	Shoaling	Dissolved Oxygen Depletion	Air Pollution	Copper Pollution
Access Channels	•	•	•				•	•	•		
Boat Basins	•	•	•				•	•	•		
Piers and Docks	•	•	•								
Boat Moorings	•	•									
Launching Ramps	•					•	•				
Bulkheads	•	•	•				•	•			
Breakwaters	•	•	•				•	•			
Marine Sanitation Devices				•					•		
Pumpout Facilities	•			•					•		
Fuel Docks	•				•						
Boats			•		•		•	•		•	•
Access Roads	•	•				•	•				
Parking Lots and Cars	•					•	•			•	
Dry Storage Areas	•					•	•				
Club Houses	•					•					
Storm Sewer Outfalls			•	•	•	•			•		
Septic Tanks				•					•		
Dredging	•	•	•				•	•	•		
Dredged Material Disposal	•	•	•			•	•	•	•		
Boat Repair & Maintenance Areas	•				•	•					•

Notes:
* All facility components are not necessarily involved in each marina.
** All impact categories are not necessarily produced at each marina.
*** Impacts may be either positive or negative.
Dots indicate a potentially significant relationship between the facility component and impact category during either construction or operation. The component may be either a source or a cause for that impact.

nesting or feeding shorebirds. Project activities should be scheduled to minimize disturbances to waterfowl, spawning fishes and shellfishes, and other biological resources at the project site. Precautions should also be taken to reduce the possibility of accidental spills or leakages of chemicals, fuels, or toxic substances during construction and operation of a marina. Effort should be expended to minimize the production and release of high concentrations of suspended sediments, especially where and when sensitive biological resources such as corals or sea grasses could be exposed to turbidity plumes and increased siltation rates. Dredging of a channel and basin in conjunction with a small boat harbor project presents a need for additional consideration of impacts in relation to suspended sediments and dredged material disposal.

(b) Long-term impacts. Long-term impacts of small boat harbor construction are less definitive or predictable. Ultimate near-field effects on littoral sediment transport can be expected to become evident within several seasonal cycles. These effects will vary according to a given project's environmental setting and specific engineering design. For example, periodic maintenance dredging will be required for catch basins adjacent to weir jetties and in the harbors. The impact that constructing coastal structures will have on far-field shore processes is presently understood only qualitatively.

4-4. Non-Point Source Pollution (Commercial and Recreational Traffic Effects)

a. Passage of commercial or recreational craft can cause drawdown, turbulence, and waves. These disturbances can erode shorelines, resuspend alluvial sediments, and scour shallow areas. Physical effects of traffic are unique in that although they may last only a few minutes, they are often repeated many times during a 24-hr period. Concern has been expressed that the physical effects of movement of commercial vessels could negatively affect aquatic biota (Rasmussen 1983; Nielsen, Sheehan, and Orth 1986). Temporary periods of turbulence or elevated suspended sediments can stress or kill pelagic fish eggs and larvae, bottom-dwelling invertebrates such as mussels, aquatic insects, worms, and crustaceans. Characteristics of large rivers, which include size, shape, bed and bank material grain size, and ambient velocity and suspended sediment concentrations, influence the nature and magnitude of traffic effects. Shallow, narrow, sinuous waterways will be more susceptible to physical forces than large waterways. Sediment is more likely to be resuspended from alluvial substrates than from cobble or bedrock. Sediment resuspension due to commercial traffic is usually most noticeable during low flow since the vessels are physically closer to the sediment. During higher flow, sediment resuspension due to traffic usually cannot be detected since the vessels are further away from the bottom and have less influence.

b. Chemical changes resulting in vessel passage are usually minor. Shifts in oxygen tension in the water column have been associated with tow-induced increases in suspended sediment (Lubinski et al. 1981). In a study by Environmental Science and Engineering (1981) it was concluded that the effects of tow passage on dissolved oxygen, specific conductance, pH, water temperature, and transmissivity adjacent to the navigation channel were nearly undetectable.

4-5. Point Source Pollution

a. General. Point sources of pollution in small boat basins can have an adverse effect on water quality in the basin and adjacent areas. These point sources of pollution may include dredging and disposal operations during harbor construction and maintenance. After construction is complete and the boat basin is in operation, point sources of pollution include storm and sanitary sewer utilities provided with the marina facilities, surface runoff, inadequate control of bilges, fueling facilities, and the dumping of garbage and trash in the harbor waters.

b. Dredging and dredged material disposal considerations. Nearly all harbor development projects will require some dredging operations. Factors influencing the amount of material that must be dredged are water depth, tidal range, size of vessels to be accommodated, distance to main navigation channels, and siltation rates. The environmental impacts associated with dredging are site-specific. Negative environmental impacts associated with dredge and disposal operations include short-term increases in turbidity, temporary reductions in oxygen content, burial of organisms, disruption of existing benthic communities, creation of stagnant water conditions, and resuspension of pollutants (Chmura and Ross 1978).

(1) During the design phase of the project, the environmental effects associated with dredging and dredged material disposal must be considered. Dredging and disposal should be accomplished using the most technically satisfactory, environmentally compatible, and economically feasible dredging and dredged material disposal procedures. The following activities are required to evaluate the environmental impacts of dredging and dredged material disposal in the design phase of the project.

Step	Information Source
(1) Analyze dredging location and quantities to be dredged.	Hydrographic surveys, project maps
(2) Determine the physical and chemical characteristics of the sediments.	Palermo, Montgomery, and Poindexter (1978)
(3) Determine whether or not there will be dredging of contaminated sediments.	Brannon (1978)
(4) Evaluate disposal alternatives.	EM 1110-2-5025
(5) Select the proper dredge plant for a given project.	EM 1110-2-5025
(6) Determine the levels of suspended solids from dredging and disposal operations.	Barnard (1978)
(7) Control the dredging operation to ensure environmental protection.	Barnard (1978)
(8) Identify pertinent social, environmental, and institutional factors.	EM 1110-2-1202
(9) Evaluate dredging and disposal impacts.	Wright (1978) Hirsch, DeSalvo, and Peddicord (1978)

(2) Limitations may be placed on dredging equipment to minimize the environmental impact of the dredging and disposal operation. If upland containment areas are small, the size of the dredge should be restricted to minimize stress on containment area dikes and provide adequate retention time for sedimentation to prevent excessive suspended solids in the weir effluent. Dredged material disposal may also be accomplished through open-water disposal and habitat development. The determination of a disposal alternative is very important in determining the environmental impact of dredging during marina construction and maintenance. Each disposal alternative involves its own set of unique considerations, and selection of a disposal alternative should be made based on both economic and environmental considerations. Detailed guidance for the selection of a disposal alternative is given in EM 1110-2-1202 and EM 1110-2-5025.

(3) The environmental effects commonly associated with dredging operations are increases in turbidity, resuspension of contaminated sediments, and decreases in DO levels. Research results indicate that the traditional fears of water quality degradation resulting from the resuspension of sediments during dredging are for the most part unfounded. More detailed information on the impacts of depressed DO levels is given in EM 1110-2-1202 and EM 1110-2-5025. Regardless of the type of dredging used, there are certain environments (e.g., spawning grounds, breeding areas, oyster and clam reefs, areas with poor circulation) and organisms (e.g., coral, sea grasses, benthos) that may be extremely sensitive to high levels of turbidity and/or burial by dredged material. It is, therefore, necessary to evaluate the potential impact of <u>each</u> proposed operation on a site-specific basis, taking into consideration the character of the dredged material, the type and size of dredge and its mode of operation, the mode of dredged material disposal, and the nature of the dredging and disposal environment. The seasonal cycles of biological activity should also be considered. Techniques to minimize environmental impacts must be employed during dredging activities. Sources of guidance on dredging activities are listed below.

Activity	Information Source
Selecting dredge	EM 1110-2-5025
Improving operational techniques	EM 1110-2-5025 Barnard (1978)
Properly using silt curtains	Barnard (1978)
Selecting appropriate pipeline discharge configurations	Barnard (1978)

(4) Most of the negative aspects of dredging operations can be eliminated or minimized. Dredging can be used to enhance the environmental quality of a water body in some cases by increasing flushing rates. Harbor basin design features that promote flushing are basin depths that are not deeper than connecting waters and gradually increase toward open water, basins with few vertical walls and gently rounded corners, and even bottom contours with no pockets or depressions (*Coastal Marinas Assessment Handbook* (USEPA 1985)). Increased turbidity and burial of organisms by siltation can be minimized by the proper use of hydraulic cutterhead dredges, filters, and silt screens as opposed to unscreened mechanical dredging. The work should be seasonably timed so as to have the least impact on certain life stages of the surrounding biota such as fish larvae or oyster spat. The duration and areal extent of these impacts are a direct function of material particle size and the flushing rate (Burrage 1988). Dredged channels should follow the course of existing channels, and slips for boats with deep drafts should be built in naturally deep water. In all cases, the harbor should not alter tidal circulation patterns, salinity regimes, or change related nutrient, aquatic life, and vegetative distribution patterns (National Marine Fisheries Service 1983). Dredged material should be viewed as a potentially reusable resource, and should include provisions for access to such resources. Permanent, upland disposal sites should be sought in preference to wetland disposal. Areas containing submerged vegetation and regularly flood-emergent vegetation should not be used.

c. Other point source discharges.

(1) Other direct sources of pollution in a small boat basin may occur during marina construction where natural vegetative cover is usually replaced with impermeable surfaces such as parking lots and buildings. These areas reduce the area available for storm-water percolation and increased storm-water runoff and pollutants. These pollutants associated with storm-water runoff may include sediments, pesticides, oil and road dirt, heavy metals, and nutrients. An immediate effect of runoff may be a temporary reduction in DO in the water. Lower DO concentrations can be lethal for most marine species. Boat basins may have low DO concentrations because of reduced water exchange rates and therefore, may be more susceptible to deoxygenating pollutants. Although heavy metals such as zinc, mercury, lead, and cadmium in their pure state usually are not particularly hazardous to marine life, these metals become quite toxic when combined with organic pollutants.

(2) Pesticides and herbicides used at marinas and their associated developments may also be washed into marina waters by runoff. These pollutants are not only harmful to marine life, but may also be accumulated by fish and shellfish and then consumed by humans. Also, petroleum products resulting from fuel spills, parking lots, and bilge draining may be toxic to marine life. Other potentially harmful runoff products include sediments, detergents, and excessive nutrients. These pollutants can result in reduced DO levels, can stimulate algal blooms and the growth of nuisance plants, and can eventually change the texture of bottom substrates and produce a zone of reduced productivity.

(3) Sanitary pollutants can enter marina waters directly discharged as untreated or macerated fecal waste from marine sanitation devices (MSDs) aboard boats or from improperly functioning or poorly located septic systems that allow sewage effluents to leach into marina waters. The most serious effect of discharging sanitary waste may be the potential for introducing disease-causing viruses and bacteria. This problem may occur if boat sewage is released in the vicinity of shellfish (clam or oyster) beds.

(4) Expected pollutant concentrations in marina basins and adjacent waters can be estimated by evaluating the type and quantity of pollutant loadings expected and the dilution and transfer of such pollutants by various flushing mechanisms. Various methods to assess the water quality impacts of marina-derived pollutants on the environment are discussed in detail in the *Coastal Marinas Assessment Handbook* (USEPA 1985).

d. Water quality mitigative measures.

(1) Water exchange does not always ensure good quality, especially in the back basins of a multibasin harbor. Sanitary-sewer and industrial waste discharges into harbor waters can be and must be eliminated in harbor planning. The flushing of sanitary facilities and dumping of pollutants must be controlled by ordinance and by provision of pumping stations and garbage and trash collection services at convenient locations. The disposal services should be capable of handling heavy weekend or seasonal usage. Trash containers should be convenient and secure to prevent litter from falling or blowing into the water. Collection facilities for boat holding tank wastes should be conveniently available at existing fueling stations. The production of boat sanitary wastes can be reduced by providing convenient shoreside restroom facilities of adequate size with hot showers and wash basins. Well-maintained restrooms will reduce boat toilet use. Other

measures to prevent sanitary waste discharges into marina waters are to require all boats with MSDs to be connected to a sanitary waste collection system when moored, sealing boat discharge outlets when they enter the marina, and banning live-aboards or requiring that these boats be permanently connected to a shoreside sanitary waste collection system.

(2) A storm-water management plan that diverts storm water away from the harbor is required to maintain water quality within the marina. If local surface water cannot be diverted from the harbor, extra care should be taken to keep harbor streets, parking lots, and other marginal surfaces reasonably clean. Also, fertilized landscapes should be prevented from overflowing when watered.

(3) Careful attention to boat maintenance and repair activities is also essential to maintaining harbor water quality. Paint spraying, sandblasting, engine repairs, boat washing, and similar maintenance activities should not take place in the harbor or near ramps or railways. These activities should preferably be performed on shore, either indoors or behind canvas screens. Also, the use of non-phosphate detergents can greatly reduce the amount of nutrients entering marina waters.

4-6. Aquatic Plant Control

a. Submersed aquatic plants can interfere with recreation, water supply, and navigation in small boat basins. Although moderate densities of vegetation improve habitat for fishes and waterfowl, nuisance levels usually have to be removed with an appropriate control measure. The following pertains to two methods of controlling submersed vegetation at small boat basins: mechanical harvesting and biological methods.

b. Mechanical harvesting of aquatic plants should be considered when areas are small, or when biological techniques are not appropriate. A mechanical harvester moves through the water, and cuts and processes the plants, which can be placed back in the water or loaded on a barge and shipped to shore for disposal. A computer model that simulates mechanical harvesting has been prepared that provides guidance on the effectiveness of various harvesting methods and the amount of time required for various harvesting strategies (Sabol 1983).

c. The white amur or grass carp (*Ctenopharyngodon idella*) has been used to control certain species of aquatic plants in lakes and ponds (Miller and Decell 1984, Miller and King 1984). Nonreproductive strains of the fish can be purchased and easily transported by truck. The fish do not compete with native fish for food or reproductive sites and are used successfully as control agents. These fish should only be used in small bodies of water where there are dense localized stands of submersed aquatic plants.